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REHABILITATION TECHNIQUES FOR CONCRETE BRIDGES

FINAL REPORT

by

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16. Abstract

This research project addresses rehabilitation techniques for reinforced and prestressed concrete bridges, focusing primarily on corrosion of prestressed concrete beam-ends. An extensive literature database on repair of concrete bridges was developed using Microsoft Access. A limited, first version of an expert system computer program, Concrete Bridge Assessment and Rehabilitation (ConBAR), was developed to assist in diagnosis of concrete bridge deterioration problems and to identify repair, rehabilitation, or preventative maintenance options. The effectiveness of several repair methods in mitigating corrosion damage and providing protection to prestressed concrete beam-ends was evaluated experimentally. These methods included silane sealers, epoxy coatings, patching, polymer (resin) coatings and fiber-reinforced polymer (FRP) wraps.

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EXECUTIVE SUMMARY

This research project addressed rehabilitation techniques for reinforced and prestressed concrete bridges, focusing primarily on corrosion of prestressed concrete beam-ends. The primary objectives of this research were: (1) to collect and synthesize information on rehabilitation methods for concrete bridges (2) to evaluate the effectiveness of preventative and corrective methods to address deterioration of prestressed concrete beam-ends and (3) to initiate development of an expert system software program to assist in the assessment, diagnosis, and repair of concrete bridges.

A comprehensive review of available literature in the field of rehabilitation of concrete bridges, especially in northern climates, was performed. The results of this review are summarized in this report. In addition, an extensive literature database on repair of concrete bridges was developed using Microsoft® Access. Information on a total of 570 papers and reports are included in this searchable database.

An initial version of an expert system computer program, Concrete Bridge Assessment and Rehabilitation (ConBAR), was developed to assist in the diagnosis of concrete bridge deterioration problems and to identify repair, rehabilitation, or preventative maintenance options. This program includes a user-friendly interface that obtains relevant information on the subject bridge through a series of questions, and provides suggestions and recommendations to the user. The depth and variety of questions that ConBAR asks the user before making recommendations far exceed the scope of previous attempts at developing such expert system tools for concrete bridges. This necessitates a very large set of expert rules (based on combinations of possible answers) that must be incorporated into the program. This

program currently includes the complete infrastructure required as well as a limited number of expert rules, which must be expanded and enhanced in future developments of this program.

Based on the results of the literature review, a test plan was developed to address corrosion-induced damage and subsequent repair of beams-ends due to chloride-laden water infiltrating through faulty expansion joints. This problem was selected for experimental evaluation because of its prevalence in northern states such as Wisconsin, and the lack of proven methods to address them. The effectiveness of several preventive solutions/repair methods in mitigating damage and providing corrosion protection was evaluated experimentally. These included localized applications of silane sealers, epoxy coatings, patching, polymer resin coating, and fiber-reinforced polymer (FRP) wraps.

A total of five 36-inch-deep, 8-ft-long prestressed concrete beam specimens were fabricated and tested. The two ends of each beam were either left untreated or were treated using different protective materials and procedures. The beam-ends were subjected to wet/dry cycles of salt-water sprays together with imposition of an impressed electric current to accelerate the corrosion process. After an initial exposure period of 6 months, some of the previously untreated beam-ends were also repaired/protected. The accelerated corrosion process was then continued. The total exposure period for all specimens was 1-½ years. A series of tests were performed during the exposure period. These included half-cell potential measurements, corrosion current measurements, strain measurements, and chloride content measurements. At the conclusion of testing, the end regions of the test specimens were partially dissected to visually examine the state of corrosion of strands.

At the conclusion of the experimental program, an evaluation of various treatments was made. These evaluations were based on the extent of cracking observed, measured chloride penetrations, and observed extent of corrosion during dissection. The best solution is determined to be treating the beam-ends from the first day, i.e. before installation in the field. The treatment area would be limited to all surfaces within a 2-ft-length at the two ends of each beam. This includes the back end surface and the bottom surface. When the strands are cut flush with the back of the beam, the treatment must cover the cut end well to prevent horizontal migration of chlorides through interstitial spaces between wires. In cases where the strands are not cut flush (i.e. embedded in the diaphragm concrete), the exposed strand must be coated well to prevent horizontal chloride migration.

This approach (treatment from the first day) is far more effective, and easier, than subsequent treatments in the field. The carbon fiber-reinforced polymer (FRP) coating, and polymer resin coating (FRP without fiber) were found to be the most effective treatments. Epoxy coating was the next best solution followed by silane treatment. As expected, leaving the beam-end untreated resulted in the worst overall performance.

Considering that the FRP wrap, polymer resin coating, and epoxy coating were generally effective, it is recommended that either polymer (resin) coating or epoxy coating be used in new construction to protect the prestressed concrete beam-ends. The FRP wraps did not significantly improve performance over polymer resin coating, and would only add to the cost and difficulty of treatment. Since protecting the end face of the beam and the cut ends of the strands are crucial, it is recommended that such treatments be performed in advance of installation in the field. The presence of diaphragms, bearings or other obstructions would likely make the field application of coatings to the beam-ends very difficult; especially after the diaphragm and deck concrete is cast.

For existing prestressed concrete beam-ends, it is recommended that the protective treatments be applied as soon as possible, before chloride levels increase significantly. It is expected that the applications of polymer resin coating or epoxy-coatings to the exposed surfaces of the beam-ends in the field would contribute, albeit not as effectively, to the protection of beam-ends in the long run, if such treatments are implemented before chloride contaminations and corrosion have taken hold. In such cases, all exposed surfaces should be treated with either polymer resin coating or epoxy coating. The extent of pre-existing chloride contamination can be measured in the field (on the bottom flange at about 2 inches from the end of the beam) and compared against chloride contents measured in areas not exposed to chloride contaminations.

In cases where corrosion and damage is advanced and has resulted in cracking and spalling of the beam-ends, the conventional patching alone would likely not be a durable repair method. Although not tested in this experimental effort, a patch repair that is subsequently coated with polymer resin coating or epoxy coating would likely provide a more effective repair.

Although the above results and recommendations were based on tests on beam-ends, it is expected that they would also be applicable to pier elements (such as pier caps and columns) and abutments.

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